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Software Project Management Approaches for Global Software Development: A Systematic Mapping Study

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Abstract: Global Software Development (GSD) is a well established field of software engineering with the benefits of a global environment. Software Project Management (SPM) plays a key role in the success of GSD. As a result, the need has arisen to study and evaluate the downsides of SPM for GSD, to thereby pave the way for the development of new methods, techniques, and tools with which to tackle them. This paper aims to identify and classify research on SPM approaches for GSD that are available in the literature, to identify their current weaknesses and strengths, and to analyze their applications in industry. We performed a Systematic Mapping Study (SMS) based on six classification criteria. Eighty-four papers were selected and analyzed. The results indicate that interest in SPM for GSD has been increasing since 2006. As a class of approaches, the most frequently reported methods (40%) are those used for coordination, planning, and monitoring, along with estimation techniques that can be used to better match a distributed project. SPM for GSD requires further investigation by researchers and practitioners, particularly with respect to cost and time estimations. These findings will help overcome the challenges that must to be considered in future SPM research for GSD, especially regarding collaboration and time-zone differences.

Key words: Software Project Management (SPM); Global Software Development (GSD); SPM approaches; Systematic Mapping Study (SMS)

1 Introduction

Global Software Development (GSD) refers to software development that is dispersed over at least two locations that are separated by national or continental borders[1]. Interest in GSD is rapidly growing as the software industry is experiencing increasing commercial globalization. In GSD, stakeholders from different national and organizational cultures and time zones are involved in software development. In this scenario, tasks at various stages of the software lifecycle may be separated for development at different geographic locations, and then coordinated using information and communication technologies[2]. While increasing the scope of organizational operations and opening up opportunities for a broader skill and product knowledge base, GSD also poses real challenges related to project diversity and complexity. As such, attention must be given to how to

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enable the successful management of software projects. According to the European Space Agency (ESA) Guide to Software Project Management (SPM)[3], SPM is a "process of planning, organizing, monitoring, controlling, and leading a software project". To be successful, software projects must effectively coordinate numerous activities by multiple organizational actors or units. SPM can also be defined as a system of procedures, practices, and technologies that address the management and measurement of software engineering[4]. SPM for GSD, in turn, involves the participation of different globally distributed managerial and technological resources to produce software of the highest possible quality with the minimum cost and development time[5, 6].

Organizations are constantly seeking ways to obtain a larger pool of skilled professionals, optimize costs, and reduce delivery times. As such, GSD projects have become a widespread reality[7]. Working in a global context has advantages as well as drawbacks[8]. On one hand, time-zone effectiveness is gained and cost is reduced in various countries. On the other hand, working on a globally distributed project[9] means increased operating costs with respect to planning and managing people due to language and cultural barriers. These differences can also create bad feelings, as more highly trained and paid engineers (who are concerned about their own job security) are asked to train their much less capable and costly counterparts[10].

Identifying the critical aspects that contribute to the success of a software project is a critical step for successfully solving the problems associated with GSD. Some SPM approaches (methods, models, frameworks, and processes) for GSD have been identified for dealing with challenges related to communication, coordination, collaboration, and performance in GSD[11]. The growing globalization of SPM has attracted a great deal of attention, and has led to the demand for specific techniques for planning, communication, coordination, and control in the management of these projects. For a global software project is to succeed, the challenges related to SPM for GSD must be identified and insights gained.

The main objective of this work was to conduct an exhaustive review and synthesize the body of current research addressing GSD project management with respect to its planning, control, and monitoring practices. The classification of related activities should be based on the main SPM bodies of knowledge and standards. We conducted a Systematic Mapping Study (SMS) to facilitate our summary of the approaches proposed for the management of distributed software projects and to address SPM deficiencies with respect to GSD[12]. Via the SMS process, we identified the most frequently addressed SPM approaches in the GSD context. The SMS study results also revealed whether the authors of selected papers based their solutions on criteria for project management, decision models, or computational techniques. Our intention in this project was to help identify suitable results and gain insight into topics to then provide an overview and a set of leading recommendations. The articles identified in this study generally present a single SPM topic related to the GSD problem, or cover two to three types of the areas in question. Moreover, the papers we reviewed address how to deal with problems associated with SPM for GSD by introducing techniques and methods, and sometimes by describing these methods and their impact on the project results.

During the life cycle of a globally distributed project, project management and control activities must be given special consideration by companies to ensure effective product development. To achieve the fixed goals of a project, project management must involve multiple activities, including the planning, scheduling, organizing, controlling, and managing of tasks and resources. Currently, based on the topics addressed in the project management problem area of distributed software development, the most important activities identified in GSD projects are planning, controlling, and monitoring, i.e., detailed project planning and strict control and monitoring during the project[13]. Research published in the literature highlights this finding, as more than 50% of researchers have investigated these activities and mentioned them as being most important for analysis and discussion[14]. This observation prompted our decision to focus on these three activities.

This paper is structured as follows: we present related work in Section 2, and identify the main SPM bodies of knowledge and standards in Section 3. We present our study research method in Section 4 and report the results we obtained from the SMS in Section 5. We discuss our main findings in Section 6, as well as the resulting implications for researchers and practitioners. We identify threats to validity in Section 7 and present our conclusions and thoughts on the future work in Section 8.

2 Related Work

Although the topic of SPM for GSD has been studied and discussed for many years, we found few literature reviews or surveys of SPM approaches for GSD. In this section, we summarize the most relevant work to date.

Hossain et al.[15] studied the use of Scrum in GSD, having found agile practices to be extremely popular in the GSD domain. The main conclusion of the authors was that it is difficult to provide solutions for GSD challenges because of the different types of development distributions across projects. The Systematic Literature Review (SLR) by Schneider et al.[16] focused on identiying challenges in global software projects and popular research areas. For researchers, in particular, the SLR provides a model on which to build and provides insight regarding which process areas are well researched. For industry practitioners, the SLR can serve as a reference framework for avaluating and improving the SPM development environment by identifying solutions in a structured manner[17].

Niazi et al.[10, 18] conducted an empirical study to identify SPM barriers in GSD that may undermine software project implementation initiatives. The authors developed a model to measure organizations' project management readiness for GSD activities, and provided a body of knowledge that can help practitioners design and implement successful SPM initiatives. To avoid the risks associated with software process improvements, SLRs also suggest key factors regarding which management areas should receive more attention. Vizcaíno et al.[19] conducted a survey of the opinions of 21 experts in SPM for GSD. These authors also analyzed the relevant GSD success factors reported in the literature that are mainly related to SPM.

Some SLRs have focused on the challenges and improvements associated with distributed projects. Jiménez et al.[7] reviewed the available literature to identify the solutions and improvements proposed up to 2009. Their paper also identifies the interest in modeling software development, and the relative benefits of approaches that dress improving productivity, quality, and the level of understanding between the team members involved in the development process. Šmite et al.[20] reported their empirical findings regarding the Global Software Engineering (GSE) related literature in terms of useful practices or techniques. Seven practices were highlighted and discussed as prerequisites for success.

In an SLR published in 2010, da Silva et al.[21] presented the best practices used in the management of distributed software development projects and their associated challenges. This SLR provided a good overview of the SPM landscape and identified the need to devise experiments to quantify evidence regarding the effect of using best practices and models.

In summary, after considering the research and publications on SPM for GSD to date, our work serves as a starting point for determining the current SPM approaches used in the GSD context. The qualitative insights provided by the above studies are particularly relevant to our research and must be taken into account when generalizing the findings of this paper. However, there has been scant work to date to comprehensively synthesize and summarize the state-of-the-art of SPM for GSD. None of the aforementioned SLRs provide any classification of activities identified in the Project Management Body Of Knowledge (PMBOK)[22], nor any synthesis of the benefits and limitations of the SPM for GSD approaches selected. On one hand, studies such as Ref. [21] focused on approaches and practices, but did not go into the issue in any depth or classify them according to relevant standards, such as PMBOK. On the other hand, a few studies have focused on SPM challenges but their finding are not sufficiently recent and their coverage of this issue is limited. To date, literature reviews have focused on specific SPM areas, such as agile management or estimation[23, 24], but there has been no systematic review that provides a more complete coverage of the main SPM areas. Given these observations, we realized the importance of using the SMS framework as a means for gaining new insights into the specification and the classification of SPM approaches for GSD. Therefore, using the PMBOK as a framework, our work consisted of collecting, synthesizing, and classifying the current and most relevant knowledge regarding SPM approaches for the GSD context.

3 SPM Bodies of Knowledge and Standards

In this section, we present our analysis of the current situation in SPM, based on the most important project management Bodies Of Knowledge (BOKs) and standards. BOKs, standards, and related assessments can be viewed as essential building blocks in the formation and recognition of a distinct SPM profession. Various organizations have worked diligently to identify related software engineering knowledge. Many BOKs and standards that include SPM content have been established to assist managers to successfully undertake SPM activities. A BOK is defined as a complete set of concepts, terms, and activities that comprise a professional domain[25], whereas standards are the result of a consensus that has been formally approved by a recognized body with the aim of achieving the optimum degree of order in a given context[26]. Overviews of the BOKs and standards that contribute to the development of a better SPM structure are presented in the subsections below.

3.1 Bodies of knowledge

• The PMBOK[22] contains the sum of knowledge in the management profession, and is divided into five basic process groups: initiating, planning, executing, monitoring/controlling, and closing. Each process group is divided up into ten management knowledge areas: integration management, scope management, time management, cost management, quality management, human resource management, communications management, risk management, procurement management, and stakeholder management.

• The Software Engineering Body Of Knowledge (SWEBOK)[27] describes knowledge in the field of software engineering, and includes ten Knowledge Areas (KAs), including engineering management, engineering process, configuration management, quality management, etc. The software engineering management KA contains five subareas: initiation, planning, enactment, evaluation, and closure.

3.2 Standards

• IEEE Std 12207-2008[28] is a guideline that can be used to define, control, and improve software life-cycle processes. This standard is applied to the acquisition of systems, software products, and services; to the supply, development, operation, maintenance, and disposal of software products and to the software portion of a system, whether it is performed within or outside the organization.

• IEEE Std 15288-2008[29] is a process standard that is intended to help organizations and projects establish an appropriate environment for the desired processes. This standard defines a set of processes and associated terminology for the full project life cycle, including conception, development, production, utilization, support, and retirement. It also supports the definition, control, assessment, and improvement of these processes.

• ISO/IEC/IEEE 16326[30] is a guideline for project management plans that cover software projects and software-intensive system projects. This guideline cancels out and replaces ISO/IEC TR 16326.

• ESA PSS-05-08[3] is an ESA guideline describing the software engineering standards to be applied in the implementation of all ESA's deliverable softwares.

• ISO 21500:2012[31] is a project management standard that provides high-level descriptions of the concepts and processes that constitute good practices in project management, which can be used by any type of organization, whether public, private, or community-based, and for any type of project, irrespective of its complexity, size, or duration.

The scope of our paper with respect to the software project issues of planning, monitoring, and controlling processes point to the PMBOK as being the most appropriate body of knowledge for area classification. In this SMS, we used the PMBOK process to group reference categories for classifying software project management proposals. Although other options are available, the PMBOK provides a standard reference with which to classify project management processes according to the project lifecycle, and is widely recognized by industry and academia. PMBOK recognizes processes that fall into five basic process groups, including the three we selected: planning, monitoring, and controlling. The objective of our study, therefore, is to identify SPM approaches in the literature that are related to the GSD field and classify them with refereneces to the PMBOK.

4 Research Methodology

An SMS is an investigation of the literature that is focused on selecting and synthesizing all the high quality research related to a particular topic, as well as providing an exhaustive summary of the current literature that is relevant to specific mapping questions, using explicit methods to identify what can reliably be stated. The principal goal of an SMS is to provide a formal means of synthesizing the information available from accessible primary studies relevant to a set of mapping questions[19]. This method can cover three main study phases: planning, conducting, and reporting. The objective of using these phases is to identify, evaluate, and interpret all available research relevant to a particular topic based on the strength of their evidence, to draw conclusions, and finally provide recommendations. Figure 1 outlines the phases of the SMS process[32].

4.1 Mapping questions

There are many ways to organize and manage distributed development. GSD can be conducted via different scenarios and be implemented in different organizational forms. The aim of implementing GSE scenarios (with respect to cost, resources, communication, quality, etc.) is to realize SPM success[33].

In this study, our goal is to gain insight into the existing

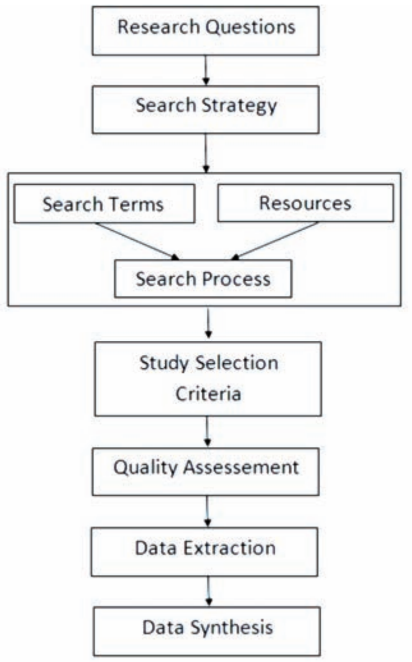

Fig. 1 Stages of SMS process.

SPM approaches for GSD. In particular, in this paper, we focus on mapping questions related to developing and evaluating a classification scheme for GSE-related studies. To validate and improve the scheme, we conducted a review, for which we selected studies reported at international conferences and in professional journals, since these particular conferences and journals focus explicitly on publishing high-quality works. Furthermore, we sought to understand existing research directions within the field of GSE and the research specific to this topic[20]. The latter is particularly important since it provides evidence about what we actually know. Due to the different strengths of the studies, findings may vary with respect to the research methods, types, and approaches. The strength of the empirical evidence in a field provides important information for making decisions about future researches and how to practice globally distributed development. Thus, this SMS addresses seven Mapping Questions (MQs), which are presented in Table 1, along with their principal motivations. These questions allow for the categorization of current research into SPM techniques for GSD and the identification of future areas of research in the field, which we used as a basis for defining the search strategy and paper selection criteria. Therefore, we emphasize the importance of describing the methods used to gather and analyze empirical data (e.g., survey, case study, experiment, or other).

4.2 Search strategy and paper selection criteria

We identified the extracted papers using specified search terms, and performed searches in the following sources in January 2016.

- IEEE Xplore digital library (http://ieeexplore.ieee.org);
- ACM digital library (http://dl.acm.org);
- ScienceDirect (http://sciencedirect.com);
- SpringerLink (http://link.springer.com);
- Google Scholar (http://scholar.google.com).

These sources were selected on the basis of systematic reviews in the same field with a similar scope. The researchers involved in the studies[7, 20, 34] used IEEE, ACM,

Table 1 Mapping questions.

ID	Mapping question	Motivation
MQ1	Which publication channels are the main targets of SPM approaches for GSD?	To identify where studies on SPM approaches for GSD research can be found in addition to the suitable targets for publications of future studies.
MQ2	How has the frequency of SPM approaches for GSD publications changed over time?	To identify the publication trends of SPM approaches for GSD research over time.
MQ3	Which approaches have been used for SPM in the GSD context?	To discover software engineering techniques, methods, and models used in SPM for GSD.
MQ4	What research methods are used in the selected papers?	To identify the research methods reported in the existing literature.
MQ5	In which research type are SPM approaches for GSD classified?	To explore the different types of research reported in the literature concerning SPM techniques for GSD.
MQ6	Which SPM activities for GSD with respect to planning, monitoring, and controlling were most frequently addressed?	To discover the most frequently occurring SPM for GSD activities.
MQ7	What are the benefits and limits of SPM approaches in GSD?	To provide a detailed analysis that identifies the benefits and limitations reported in the literature.

and Sciencedirect libraries. To include more results, we also used two additional search sources (SpringerLink and Google Scholar), from which we identified a set of professional software engineering journals and events (such as ICGSE, ICSE, CSCW, CCECE, APSEC, and ESEC).

To answer the MQs, we searched for research papers with a background and main focus on GSD and SPM. Although the search terms selected for extracting the relevant papers do not cover all possible research methods, we consider them to be sufficient in their coverage of in-depth studies related to our research scope, since we were seeking papers with depths characteristic of those identified in an SMS.

We grouped search terms with similar meanings and obtained combined terms using the **OR** logical operator between search terms in the same group. To perform automatic searches in the selected digital libraries, we formulated a search string using the **AND** logical operator between combined terms of different groups, as follows:

(Software **OR** system* **OR** application*) **AND** (project* **OR** process* **OR** product*) **AND** (manag* **OR** improv* **OR** assess* **OR** develop* **OR** monitor* **OR** plan* **OR** control* **OR** coordinat* **OR** perform*) **AND** (technique* **OR** method* **OR** need* **OR** approach* **OR** factor* **OR** model* **OR** strateg* **OR** best practices **OR** measur*) **AND** (Global development **OR** Global engineering **OR** distributed development **OR** outsourc* **OR** Offshor* **OR** Dispersed development).

This search string was inspired by those used in similar research[21, 35] and also from authors' suggestions. We applied this search string to the titles, abstracts, and keywords of papers to reduce the search results[36]. Each paper was retrieved by the first author and specific information about each relevant paper was extracted and entered in a Microsoft Excel file, as shown in Fig. 2.

Two authors were each responsible for retrieving papers by considering each paper's title and abstract. When there was a disagreement, the full text was accessed to reach an agreement. The paper was then included, excluded, or classified as uncertain. Two other researchers were asked to review the selected papers on the basis of their titles and abstracts. Papers were included if both researchers agreed that the study was relevant and was excluded if both researchers agreed that the paper was irrelevant. Papers that were judged differently were discussed until an agreement was reached. The Kappa coefficient for this selection process was 0.9, which indicates almost perfect agreement between the two assessments[37]. The final selection was reviewed by the remaining authors involved in this study.

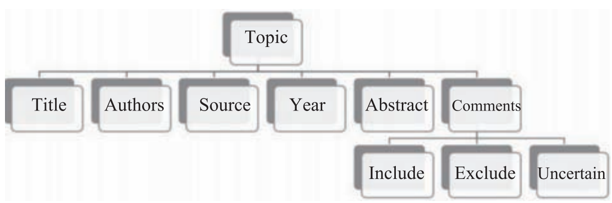

Fig. 2 Fields on the selection sheet.

The first step after the application of the search string was to eliminate duplicate titles and papers that were clearly outside the study scope. Potential primary studies were then selected using the inclusion/exclusion criteria. To focus on studies that had presented management mechanisms, paper selection was accomplished without considering the development aspect.

We defined the following inclusion and exclusion criteria based on established SMS guidelines[12]. Note that the inclusion criteria are linked by an "**AND**" to join the main criteria and thereby ensure the pertinence of the selection, whereas the exclusion criteria are linked by an "**OR**" to indicate that compliance with only one criterion is sufficient for the paper to be excluded.

(1) Inclusion criteria.

• IC1: Papers related to the SPM aspect of GSD projects.

• IC2: Studies that address SPM approaches related to the PMBOK process groups "Planning" and "Monitoring and Controlling".

(2) Exclusion criteria.

• EC1: Papers that are not published in journals, conferences, or workshops.

• EC2: Papers that are a workshop summary.

• EC3: Papers that are not in English.

4.3 Quality assessment

Quality assessment in a systematic review is a major focus that increases its depth. To enhance our study results, we designed a questionnaire to assess the quality of candidate papers. We used a scoring technique based on those used in previous studies[38, 39]. The scoring plan, as shown in Table 2 (columns (a), (b), (c), and (d)), is as follows:

(a) The paper has been published in a recognized and stable journal or conference. This question was rated by considering the Computer Science Conference using the rankings published in Computing Research and Education (CORE) 2013 Conference Rankings (http://www.core.edu.au/coreportal), and 2013 Journal Citation Reports (http://webofknowledge.com/JCR) (JCR) lists. Possible answers to this question were as follows:

Table 2 Mapping questions and quality assessment.

Paper	Classification					Quality assessment				
	Channel	Year	Research type	Research method	Approach	(a)	(b)	(c)	(d)	Score
[34]	Journal	2013	Review	Case study	Method	2	1	1	1	5
[40]	Journal	2006	Evaluation	Review	Model	2	1	1	1	5
[41]	Journal	2004	Solution	Case study	Process	2	1	1	1	5
[42]	Journal	2005	Solution	Case study	Process	2	1	1	1	5
[8]	Journal	2001	Experience	Case study	Method	2	1	1	1	5
[43]	Journal	2003	Evaluation	Survey	Method	2	1	1	1	5
[19]	Journal	2013	Evaluation	Survey	Framework	2	1	1	1	5
[44]	Journal	2011	Evaluation	Case study	Method	2	1	1	1	5
[16]	Journal	2013	Solution	Case study	Model	1.5	1	1	1	4.5
[45]	Conference	2005	Experience	Case study	Method	1.5	1	1	1	4.5
[46]	Journal	2014	Solution	Case study	Method	1.5	1	1	1	4.5
[47]	Journal	2014	Experience	Case study	Method	1.5	1	1	1	4.5
[48]	Journal	2010	Solution	Case study	Method	1.5	1	1	1	4.5
[49]	Journal	2006	Experience	Case study	Method	2	1	0	1	4
[50]	Journal	2006	Experience	Case study	Framework	2	1	0	1	4
[51]	Conference	2007	Solution	Case study	D.M. technique	1	1	1	1	4
[52]	Conference	2010	Evaluation	Case study	Method	1	1	1	1	4
[53]	Conference	2012	Evaluation	Case study	Method	1	1	1	1	4
[54]	Journal	2015	Evaluation	Review	Framework	2	1	1	0	4
[55]	Journal	2008	Evaluation	Case study	Method	1	1	1	1	4
[56]	Journal	2014	Solution	Case study	Model	1	1	1	1	4
[57]	Journal	2014	Experience	Case study	Framework	2	1	0	1	4
[58]	Conference	2006	Experience	Case study	D.M. technique	0.5	1	1	1	3.5
[59]	Workshop	2012	Evaluation	Case study	D.M. technique	0.5	1	1	1	3.5
[60]	Conference	2011	Solution	Case study	Method	0.5	1	1	1	3.5
[2]	Conference	2006	Evaluation	Case study	Process	0.5	1	1	1	3.5
[61]	Conference	2006	Evaluation	Case study	Method	0.5	1	1	1	3.5
[62]	Conference	2008	Evaluation	Case study	Process	0.5	1	1	1	3.5
[63]	Conference	2011	Experience	Experiment	Method	0.5	1	1	1	3.5
[64]	Conference	2006	Evaluation	Case study	Framework	1.5	1	0	1	3.5
[65]	Conference	2010	Evaluation	Survey	D.M. technique	0.5	1	1	1	3.5
[66]	Conference	2011	Evaluation	Case study	Method	0.5	1	1	1	3.5
[67]	Conference	2007	Evaluation	Case study	Other	0.5	1	1	1	3.5
[68]	Conference	2006	Solution	Case study	D.M. technique	0.5	1	1	1	3.5
[69]	Workshop	2009	Evaluation	Survey	Method	1.5	1	0	1	3.5
[21]	Conference	2010	Evaluation	Survey	Model	0.5	1	1	1	3.5
[70]	Conference	2012	Solution	Case study	Framework	0.5	1	1	1	3.5
[71]	Conference	2006	Evaluation	Survey	Model	0	1	1	1	3
[72]	Journal	2010	Evaluation	Experiment	Method	1	1	0	1	3
[73]	Conference	2013	Experience	Case study	Method	1	1	0	1	3
[74]	Journal	2001	Evaluation	Case study	Framework	2	0	0	1	3
[75]	Conference	2013	Solution	Case study	D.M. technique	0	1	1	1	3
[76]	Conference	2001	Evaluation	Case study	Model	1	1	1	0	3

(To be continued)

Table 2 Mapping questions and quality assessment. (Continued)

Paper	Classification					Quality assessment				
	Channel	Year	Research type	Research method	Approach	(a)	(b)	(c)	(d)	Score
[77]	Conference	2015	Evaluation	Case study	Framework	0	1	1	1	3
[78]	Conference	2015	Review	Theory	Other	0	1	1	1	3
[10]	Journal	2010	Evaluation	Survey	Process	2	0	0	1	3
[79]	Workshop	2012	Solution	Experiment	Model	0	1	1	1	3
[80]	Journal	2013	Evaluation	Case study	Method	1.5	0	0	1	2.5
[81]	Conference	2015	Evaluation	Experiment	Method	0.5	1	0	1	2.5
[82]	Conference	2009	Evaluation	Case study	Model	0.5	1	1	0	2.5
[83]	Conference	2009	Evaluation	Survey	Method	0.5	1	0	1	2.5
[84]	Conference	2002	Evaluation	Case study	Other	1	0.5	0	1	2.5
[20]	Journal	2010	Evaluation	Theory	Process	1.5	0	0	1	2.5
[85]	Conference	2007	Solution	Case study	Method	0.5	1	0	1	2.5
[7]	Journal	2009	Evaluation	Theory	Model	1.5	0	0	1	2.5
[86]	Conference	2006	Evaluation	Case study	D.M. technique	0.5	1	0	1	2.5
[87]	Conference	2013	Evaluation	Case study	Model	0.5	1	0	1	2.5
[88]	Conference	2004	Evaluation	Case study	Method	0.5	1	0	1	2.5
[89]	Conference	2011	Experience	Case study	Process	0.5	1	0	1	2.5
[13]	Conference	2011	Evaluation	Case study	Model	0.5	1	0	1	2.5
[90]	Conference	2000	Evaluation	Theory	Method	0.5	1	1	0	2.5
[91]	Conference	2010	Evaluation	Case study	D.M. technique	0	1	0	1	2
[60]	Conference	2011	Evaluation	Case study	Model	0	1	0	1	2
[92]	Conference	2005	Evaluation	Case study	Method	1	0	0	1	2
[93]	Conference	2009	Evaluation	Survey	Process	0.5	0.5	0	1	2
[94]	Conference	2009	Evaluation	Case study	Method	0.5	0.5	0	1	2
[95]	Conference	2008	Evaluation	Case study	Other	0.5	0.5	0	1	2
[96]	Workshop	2012	Evaluation	Experiment	Method	0	1	0	1	2
[97]	Conference	2012	Evaluation	Case study	Other	0	1	0	1	2
[98]	Conference	2009	Evaluation	Case study	Method	0	1	0	1	2
[99]	Conference	2003	Solution	Case study	Model	0	1	0	1	2
[100]	Conference	1998	Evaluation	Case study	Model	0	1	0	1	2
[101]	Journal	2015	Evaluation	Case study	Method	1	1	0	0	2
[102]	Journal	2010	Evaluation	Case study	D.M. technique	0.5	0	0	1	1.5
[103]	Conference	2008	Evaluation	Case study	Other	0.5	0	0	1	1.5
[104]	Journal	2014	Evaluation	Experiment	Method	0.5	1	0	0	1.5
[105]	Conference	2009	Evaluation	Case study	Method	0.5	0	0	1	1.5
[106]	Conference	2012	Solution	Case study	D.M. technique	0.5	1	0	0	1.5
[11]	Workshop	2012	Evaluation	Experiment	Process	0.5	0	1	0	1.5
[107]	Conference	2008	Evaluation	Survey	Method	0	1	0	0	1
[5]	Conference	2009	Evaluation	Case study	Model	0	1	0	0	1

• For conferences and workshops:
– "Very relevant (+2)" if it is ranked CORE A*;
– "Relevant (+1.5)" if it is ranked CORE A;
– "Not so relevant (+1)" if it is ranked CORE B;
– "Not relevant (+0.5)" if it is ranked CORE C;
– "No ranking (+0)" if it is not in CORE ranking.

• For journals:
– "Very relevant (+2)" if it is ranked Q1;
– "Relevant (+1.5)" if it is ranked Q2;
– "Not so relevant (+1)" if it is ranked Q3;
– "Not relevant (+0.5)" if it is ranked Q4;
– "No ranking (+0)" if it is not in the JCR ranking.

(b) The main focus of the paper is the SPM approach used in the GSD context, and the main goal of the paper was to discuss SPM approaches in the GSD context. Yes (+1); Partially (+0.5); No (+0).

(c) The paper presents and/or explicitly assesses an approach for solving GSD project management challenges.

The study is given a full score if it presents a new or assesses an existing approach. Yes (+1); No (+0).

(d) The study used an empirical approach and presented relevant data for our SMS. The empirical results address the use of SPM approaches for GSD. Yes (+1); No (+0).

4.4 Data extraction strategy

We based our data extraction strategy on obtaining a set of possible answers to the MQs. We used a spreadsheet to record data relevant to each article, which are presented in Table 3. The strategy is explained below.

MQ1: The publication source and channel were identified for each paper.

MQ2: Articles were classified by year to identify any publication trends.

MQ3: Approaches were classified based on the technique reported in Ref. [108].

• Data mining techniques: Software companies use a number of complex algorithms and techniques to identify data patterns and trends. These techniques analyze data in different ways.

• Methods: A certain procedure and series of steps are taken to best match the characteristics and contexts of SPM for GSD.

• Models: A description of a system or process that enables the inspection of SPM activities for GSD.

• Process: A series of actions, techniques, or functions that lead to SPM results and the performance of data operations.

• Framework: A real or conceptual structure intended to serve as a support or guide for SPM in the GSD context.

• Other: For example, tool-based techniques and any other approach not listed above.

MQ4: The research methods used in SPM for GSD can be classified as reported in Ref. [109].

• Case study: An empirical inquiry that investigates an SPM phenomenon within a real GSD context.

• Survey: A method for collecting quantitative information concerning an SPM technique for GSD.

• Experiment: An empirical method applied under controlled conditions, using subjects to evaluate an SPM approach for GSD.

• Other: For example, theoretical analysis and any research method not listed above.

MQ5: Every research type can be classified into one of the following categories[12, 110]:

• Evaluation research: Existing or new approaches implemented in practice. An evaluation or a validation of each technique is conducted including comparative studies and analysis of SPM approaches for GSD.

• Solution proposal: When a solution is proposed, it may be a new SPM approach for GSD or a significant extension of an existing approach.

• Experience: Papers expressing the author's personal experience and an explanation of what was done and how it was realized in practice.

• Other: For example, theoretical or opinion papers.

MQ6: SPM is the part of project management during which software projects are planned, implemented, monitored, and controlled. After identifying the scope of the project, estimating the work involved, and creating a project schedule, a project plan is developed to describe the tasks that will lead to completion. The objective of project monitoring and control is to keep the team and managers updated on the project's progress. Every time a change is required, change control is used to keep track of the product updates. To ensure the success of the project in a GSD setting, particular care must be taken in these more challenging areas. We chose the PMBOK since we believed it would help us to identify a reference model with which to present our work.

The main SPM activities for GSD we selected for the study are the PMBOK areas[111] related to the process groups of planning, monitoring, and controlling. We excluded the project risk management knowledge area since there is a wide body of work in the literature concerning risk management and GSD, which has been reviewed in a number of studies and SLRs, such as Refs. [112, 113]. The study areas we adopted are shown below.

• Project Integration Management, in which the processes include those needed to identify and coordinate various project management activities.

– Develop project management plan;

– Monitor and control project work.

• Project Scope Management, in which the processes comprise those needed to ensure the inclusion of all the

Table 3 Paper data extraction form.

Paper ID	Authors	Title	Publication source	Year	Approach	Research method	Research type	Activity	Benefit/ Limit
**	**	**	MQ1	MQ2	MQ3	MQ4	MQ5	MQ6	MQ7

work required by the project. To successfully complete a project, the steps are as follows:

– Plan and scope management;

– Validate and control scope.

• Project Time Management, in which the processes are those required to realize a timely completion of the project.

– Define activities and plan schedule management;

– Control schedule.

• Project Cost Management, in which the processes include planning, estimating, budgeting, and controlling the costs of the project. This aspect can be applied to

– Plan, estimate, and determine costs;

– Control costs.

• Project Quality Management, in which the organizational activities are those that will determine the project policies, objectives, and responsibilities related to quality.

– Plan quality management;

– Control quality.

• Project Human Resource Management, in which the processes include those that are used to organize and manage the project team members.

– Plan human resource management.

• Project Communication Management, in which the processes are those required to ensure the timely and appropriate generation, collection, and distribution of project information and to narrow any gaps in communication exchange.

– Plan communications management;

– Control communications.

MQ7: A detailed analysis of the qualitative findings of the papers included in the review is provided by identifying the benefits and limitations of the approaches used in SPM for GSD, as described by the authors.

5 Results

In this section, we present and discuss the findings of this review. First, we present an overview of the selected studies and then we report the review findings for the MQs listed in Table 1.

5.1 Overview of selected studies

The search string that was applied to the various digital libraries and search engines returned a high number of results (54 233) for papers that had been published during the years 1998–2015. We eventually selected just 84 of these papers as being relevant to our subject.

Figure 3 shows an overview of the search process

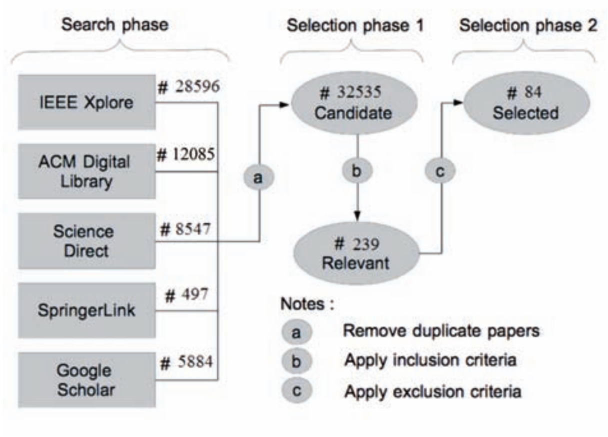

Fig. 3 Search and selection process.

and the number of studies remaining after each step of the selection process. In total, after the application of the inclusion criteria, we identified 239 papers concerning SPM for GSD, which were entered into the Excel file. When the same paper appeared in more than one source, it was considered only once, based on the order of the sources. Then, we used exclusion criteria to exclude another 155 studies, with a final result of 84 studies. Table 4 shows the results per source after the inclusion and exclusion processes.

Table 2 lists the selected papers with details regarding their classifications and quality assessments. Note that 70% of the papers scored higher than or equal to the average score of 2.5 points.

Authors of all systematic reviews emphasize that it is essential to assess the quality of the studies selected. This quality assessment is a major step in obtaining a general view of a paper's impact on the subject[12]. Table 5 shows a five-level quality classification. Although 18 of the selected papers were rated as having a low quality level, they contain some useful information, particularly regarding software projects, and the important aspect of characterizing the link between SPM and GSD. The quality classification scheme of the selected studies shows that 97.6% of the relevant papers scored higher than 1. Table 2 shows the score details for each of the studies selected.

Table 4 Source results.

Source	Relevant studies	Selected studies
IEEE Digital Library	133	52
ACM Digital Library	52	15
Science Direct	28	9
SpringerLink	5	3
Google Scholar	21	5
Total	239	84

Table 5 Quality levels of relevant studies.

Quality level	Papers	Percentage (%)
Very high ($4 < score \leqslant 5$)	13	15.5
High ($3 < score \leqslant 4$)	26	30.9
Medium ($2 < score \leqslant 3$)	24	28.6
Low ($1 < score \leqslant 2$)	19	22.6
Very low ($0 < score \leqslant 1$)	2	2.4

5.2 Publication channels (MQ1)

As shown in Table 6, 63% of the selected papers had been presented at conferences, which indicates that this is the most frequent source. Table 7 lists the journals and conferences in which the papers selected for this SMS were published. With regard to journals, the journals *IEEE Software* and *Information and Software Technology* were the most frequently recurring publication sources for the SPM for GSD topic. With respect to conferences, the International Conference on Global Software Engineering (ICGSE) was the most frequent source of publications on this topic.

5.3 Publication trend (MQ2)

According to Fig. 4, interest in SPM for GSD began in 1998. In 2010, Šmite et al.[20] mentioned globalization as being a recent field. In fact, the most relevant studies on this subject have been conducted since 2000. Interest in the topic reached its peak in 2006, the year of the first edition of the ICGSE conference, after which, in 2009, interest in this subject began to stabilize.

Table 6 Publication channel.

Publication channel	Selected papers	Percentage (%)
Conference	50	59.5
Journal	29	34.5
Workshop	5	6
Total	84	100

Table 7 Distribution of selected studies: Journal (J) and Conferences (C).

Publication channel	Type	Paper	Total
IEEE Software	J	[8, 40, 41] [42, 50, 74]	6
Information and Software Technology	J	[10, 19, 34] [44, 49, 54]	6
Empirical Software Engineering	J	[20, 48, 56]	3
Information Systems Management	J	[102, 114]	2
International Conference on Global Software Engineering (ICGSE)	C	[2, 13, 21, 58] [60–63, 65] [66, 67, 81, 82] [83, 89, 93, 103] [105, 106]	19
Electrical and Computer Engineering (CCECE)	C	[68, 88]	2
Annual Hawaii International Conference on System Science	C	[64, 99]	2
International Conference on Software Engineering (APSEC)	C	[45, 90]	2
Science and Information Conference (SAI)	C	[76, 78]	2
Others	—	—	15

5.4 SPM approaches for GSD (MQ3)

Figure 5 shows a pie chart of the selected paper categories of SPM approaches for GSD. Thirty-nine percent of the selected studies fall within the "method" category, in which the majority is of agile methods (61%) that rely on communication. This category also includes several data mining techniques (14%) that address the challenges of software cost and effort estimations[51, 65, 86], which represent crucial activities in the software development life cycle. These techniques also help to reduce costs and improve GSD productivity and quality (e.g., Genetic Algorithms (GA) and Case-Based Reasoning (CBR)).

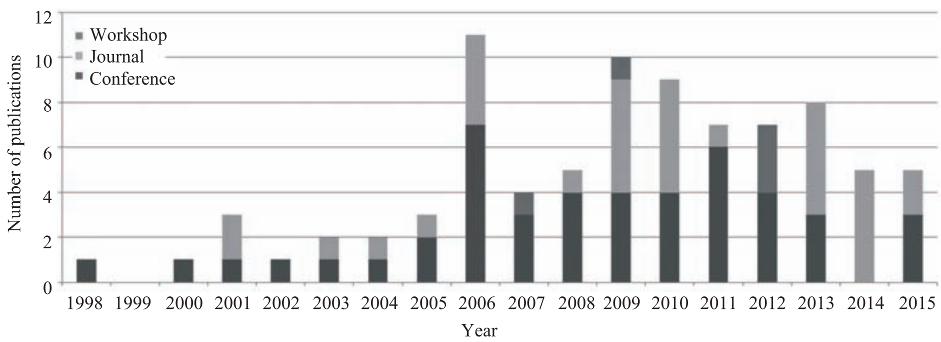

Fig. 4 Publications per year.

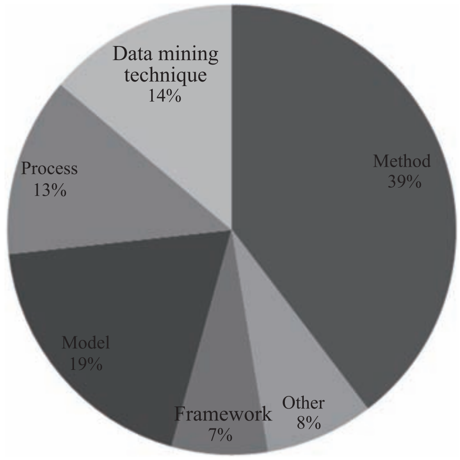

Fig. 5 SPM for GSD approaches.

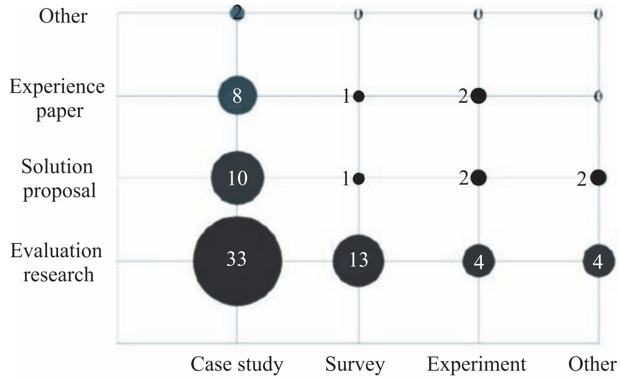

Fig. 6 Research methods and research types.

We also identified models[60, 71, 79] for GSD representation, which standardize and systematize the requirement specifications of the interaction between work teams that are physically distant from each other. These models support project planning and process improvement in GSD. The model approach, which represents almost 19% of the total categories, takes into consideration the system dynamics and continuous factors and their interactions, including communication, coordination, cultural issues, the learning curve, changing staff levels, and dynamically varying productivity[71]. The most frequently used models are estimation models (26.6%).

About 13% of the categories were processes, principally the Delphi process. Finally, frameworks comprise nearly 7% of the categories, particularly the Resource-Based View (RBV) and dynamic capabilities frameworks.

5.5 SPM approaches for GSD research methods (MQ4)

Almost 94% of the selected studies related to SPM approaches for GSD employed one of the following three main research methods: case study (48 papers), survey (10 papers), and experiments (6 papers), as shown in Fig. 6. The "other" type refers to the remaining research methods such as theoretical analyses.

Seventy percent of the selected papers include case studies, which indicate the feasibility of this approach. Each case was conducted to evaluate a concept, starting with an evaluation of the goals and methods, then a description of the project, and finally project execution to produce results and discuss their implications[66]. Fifteen percent of our selected papers include surveys.

A procedure for considering costs and the dependencies between projects must be established[100] to ensure effective planning, scheduling of distributed tasks and the application of corrective measures and notifications. The key to a project's success is in making improvements based on the needs of the company, taking into account the technologies and methodologies used and establishing an efficient communication mechanism between the members of the organization. Development tasks can be automated by requesting a registration of activities with information on pending issues[65].

5.6 Research type of SPM for GSD papers (MQ5)

Figure 6 shows the type of research undertaken in the selected papers. The most frequent type is evaluation research at 70.5%, followed by solution proposals. Three papers in the SMS present only a qualitative evaluation by the provision of guidelines and theory but no empirical data. Although there is a predominance of solution proposals and experience reports published from 2000 to 2007, the focus has recently shifted to the validation and evaluation of SPM approaches in the GSD setting, which indicates that the main concern of researchers regarding SPM in the GSD domain is to evaluate and validate techniques with which to enhance SPM for GSD.

This result indicates that the SPM-for-GSD domain is not yet a mature field[20], particularly with respect to testing hypotheses and utilizing approaches and tools. Researchers are still seeking approaches that will enhance SPM for GSD and are generating papers in which software engineering methods, techniques, and tools are evaluated in industrial environments where GSD is practiced[90]. The typical challenges of Global Software Engineering (GSE) have been identified as task coordination and allocation, collaboration and knowledge management, and resource estimation and effort[5]. These problems are related to the communication and coordination between global teams, team performance, and development costs. To solve these issues, an approach must utilize steps with which to define and standardize work processes across sites, conduct project retrospectives, and describe work processes[95].

5.7 SPM activities for GSD (MQ6)

Systematic software development is a process in which team members with different skills perform different activities[100]. We classified the selected papers according to the activities in which they were mainly involved. To do so, we used the following PMBOK process groups: planning, monitoring, and controlling. These process groups include the following knowledge areas: (1) project integration management (19.6%), (2) project scope management (15.6%), (3) project time management (11.8%), (4) project cost management (11.8%), (5) project human resource management (19.6%), and (6) project communication management (21.6%).

Table 8 provides a summary of these activities, in which the second column specifies the activity of each knowledge area. The fourth column lists the papers in which these activities are identified. The most important finding is that 21.6% of the selected papers address project communication management issues, which indicates that communication plays a critical role in the success or failure of a GSD team[49].

5.8 Benefits and limitations of the use of SPM approaches in GSD (MQ7)

The SPM literature mentions many approaches related to GSD, each of which has the potential to facilitate the management of distributed development. Table 9 summarizes the benefits and limitations of these approaches.

Agile-based management methods, which have been successfully used in distributed projects[61], emphasize explicit communication, and provide many useful communication practices. Many of these papers describe methods related to agile-based approaches, i.e., extreme programming (XP), scrum, feature-driven development, and Crystal. Some common goals of these methods are to support coordination between parties and to lessen reliance on heavy upfront planning[68].

The "model" approach includes: (1) the Constructive Cost Model (COCOMO), which minimizes the language gap, (2) the Capability Maturity Model Integration (CMMI) model[13, 98], which identifies best practices that help collaborative organizations to improve their processes, and (3) estimation models[65] to enable the recording of difficult but necessary decisions made in the management of GSD to guide the project to success. It is not possible to correlate these estimation models with the number of locations involved in a distributed project. The results based on an analysis of the data gathered by the selected papers indicate that estimating the effort expended in GSD projects remains difficult. Although the results do indicate that some models were determined to be more appropriate than others, these findings must be analyzed with caution, as they do not enable researchers to use existing metrics to validate their perceptions about the models' estimation accuracies.

The data mining techniques employed can apply GAs to identify project purposes. This approach also includes CBR[59], which is a technique used to resolve new problems based on the solutions identified for analogous past problems. CBR is therefore a solution option that eases the problems associated with the recovery and application of knowledge in GSD. Unlike GA technology, the CBR

Table 8 SPM activities for GSD.

Knowledge area	Activity	Number of papers	Paper
Project integration management	Coordination Organization Decision management	12	[7, 13, 55, 59, 68, 70] [77, 85, 92, 93, 106] [107]
Project scope management	Knowledge management Requirement management	8	[11, 40, 41, 53, 69, 80] [94, 104]
Project time management	Planning and scheduling Time estimation	7	[50, 56, 60, 71, 95, 100] [115]
Project cost management	Cost estimation Effort estimation	8	[44, 58, 65, 74, 75, 81] [86, 115]
Project human resource management	Collaboration Team management	10	[8, 63, 64, 72, 79, 83] [97, 102, 103, 105]
Project communication management	Communication Cooperation	19	[2, 34, 43, 45, 48, 49, 61] [62, 66, 67, 76, 77, 82, 84, 88−91, 96]

Table 9 Benefits and limitations of the approaches used in SPM for GSD (MQ7).

Type	Approach	Benefits (+) and limits (−)	Paper
Method	Agile based management method: *Scrum*, *Extreme programming*, *Feature Driven Development*, *Crystal*	(+) Facilitates task coordination and allocation decisions. (+) Brings transparency of work progress to all partners and provides a good picture of how the project is progressing. (−) Difficulties in transferring the context to different projects even within the same organization.	[48, 49, 53] [60, 61, 68] [80, 88, 96] [104, 114]
	Flow mapping	(+) Incorporates communication at all stages of the project. (+) Makes it easy to plan and manage communication, especially when team-building takes place. (−) Becomes out of date (with respect to maintaining visualization of the flow map) and the execution of conformance analysis is very expensive.	[66]
	Change management method	(+) Helps to organize and track development work. (+) Provides mechanisms with which to revise the code and some ability to manage concurrent changes in a structured way. (+) Makes it easy to find and contact an appropriate expert, using change history data. (−) Slows the work down.	[43]
	VTManager	(+) Provides a set of effective guidelines and activities for training, developing, and managing. (+) Can be adapted to different circumstances that usually arise in global software projects. (+) Determines effectiveness and efficiency: gathers and analyzes data in the time needed for preparation and launch. (−) Difficulties in its application to different types of teams.	[72]
	Knowledge Management	(+) Simplifies the process of sharing, distributing, creating, capturing, and understanding the company's knowledge. (+) Allows team members to revisit and better understand the data at a later time. (+) Provides correct and complete understanding of the needs, and effectively contributes to the growth and utilization of knowledge. (−) Uninterrupted commitment of the team is vital for effective cooperation.	[53, 69]
	Earned Value Management (EVM)	(+)Measures project performance and progress. (+) Identifies important participants to administration of project contracts. (−) Requires sufficient project management knowledge, training and experience.	[98, 116]
Model	Estimation models: *Planning Poker based model*, *Function points based model*, *Use case points based model*	(+) Permits the recording of difficult decisions that must be made in the management of GSD. (−) It is not possible to correlate the estimation model being used with the number of locations involved in a distributed project	[65, 75]
	Multi-criteria decision model	(+) Describes the interactive process of modeling used to develop the project in detail. (+) Helps to facilitate forward movement during group discussions. (−) There is a lack of information on the globality of the tasks when dividing the project into independent tasks.	[60, 115]
	CMMI	(+) Analyzes potential causes of weaknesses and defines improvement goals. (−) Needs good awareness of the problems to find solutions and design a new model.	[5, 13, 98]
	COCOMO	(+) Minimizes cross-site communication and facilitates communication among remote collaborating teams. (+) Widely used and accepted internationally and by organizations of all sizes for estimating cost of software projects. (−) Needs extra effort to understand what is behind the data.	[51, 86]

(To be continued)

Table 9 Benefits and limitations of the approaches used in SPM for GSD (MQ7). (Continued)

Type	Approach	Benefits (+) and limits (−)	Paper
	Procura	(+) Allows planning and scheduling of agent-based design projects in a hierarchical top-down approach.	[100]
	CoMo-Kit	(+) Improves processes using descriptive modeling and implements methodologies for project planning.	[100]
	Global Teaming Model	(+) Ensures consistency and compatibility among recommendations, and avoids conflicting strategies. (−) The knowledge base of the model needs more refinement.	[79]
	GSD model	(+) Enables explicit representation of the process structure and mechanisms used to transfer work products and to coordinate activities in GSD.	[94]
	Hybrid simulation model	(+) Exploits the efficiencies of standard schemas and representations to support project planning and process improvement in distributed projects. (−) Needs real-world data in order to calibrate the model to a specific project.	[40, 71]
Process	Delphi	(+) Collects responses and factors from difficult decisions identified by GSD management (assigning work packages, choosing coordination mechanisms and tools, and selecting internal personnel). (+) Attempts to obtain a consensus from a group of experts using repeated responses from questionnaires and controlled feedback. (−) A meaningful group of experts must be identified and managed in time.	[102]
	Software Process Improvement	(+) Helps organizations to develop higher-quality software.	[53]
Data mining technique	Quadratic Assignment Procedure (QAP)	(+) Runs the correlations and multiple regression analyses with respect to communication. (−) Provides sensitive results for particular methods and options implemented in standard software packages.	[58]
	GA and MOEA	(+) Generates the most optimum allocation pattern considering the project goals. (+) Helps the project manager by balancing various objectives and generating sets of optimized schedules for each individual team member. (−) Must be enhanced for multiple project situations	[68, 106]
	Fuzzy similarity	(+) Determines the similarity score among the knowledge components. (−) Similarity measures are affected by irrelevant factors, thus decreasing the estimation accuracy.	[91]
	Case-Based Reasoning (CBR)	(+) Solves problems related to the application of knowledge in GSD using previous solutions stored in the system (−) Lack of flexibility in the knowledge representation.	[59]
Framework	Resource Based View (RBV)	(+) Identifies the key project management capabilities associated with offshore application development. (+) Provides richness and depth of information. (−) Has limited ability to provide any reliable predictions.	[64]
	Dynamic Capabilities	(+) Improves the resources to better meet the needs of a changing competitive environment.	[64]
	Information Quality Management Framework (IQMF)	(+) Assessment and improvement of the data/information quality within the GSD Project Management.	[5]

methodology indicates how to solve problems at a particular time using previously stored solutions without the need to specify a particular technology.

The Delphi process also provides responses to difficult decisions in GSD management[102], such as choosing coordination mechanisms and tools, selecting a methodology, and assigning work packages. Table 9 also highlights the benefits and limitations of the main frameworks. Despite the limited predictions of RBV, this framework provides a wealth of in-depth information on offshore application development.

6 Discussion

In this section, we summarize and discuss our main SMS findings and identify some implications for researchers and practitioners.

6.1 Principal results

Our goal in this SMS was to provide an overview of the current literature on SPM approaches for GSD, evaluate the quality of the papers studied, and detail our specific findings based on the seven study criteria.

• **MQ1 and MQ2**. The study results confirm that SPM for GSD has maintained a high level of importance and, since the publication of the first SPM for GSD study in 1988[100], this area continues to attract the attention of researchers and practitioners. In recent years, studies have been published in journals and conference proceedings, including the ICGSE conference proceedings in particular. The most productive research period of SPM for GSD began after the publication of the first edition of this conference in 2006. This shows that progress in the field of GSE began with the topic of outsourcing at the end of the last century, which led companies to build international corporations and establish development sites for multi-national companies in different countries[20].

• **MQ3**. We found the literature to typically consider the importance of decision support in distributed project management in the task allocation context[117]. A careful plan must be established to ensure the effective integration of agile methods in GSD. The development of complex products using agile development methodologies began in the 1990s[60]. These methods, which have also been applied to GSD to help solve complex problems, rely on frequent communication and quick feedback and reduce the emphasis on documentation. In the GSD context, an agile team is cross functional in that, in its entirety, it has a complete range of the skills needed to perform software development activities and deliver value to customers.

The SMS outcomes indicate that the main inspiration for research into SPM for GSD has been software engineering research on distributed software development. We can divide global software projects into two categories[118]: relationship structure and geographic work location. The former refers to the development of software via an outsourcing or insourcing arrangement, whereas the latter concerns where the project is performed, i.e., offshore (located in a different country to that of the client organization) or onshore (located in the same or a nearby country). The project types within these two dimensions form a simplified matrix of GSD business models[119]. The selected papers mainly (90%) deal with the offshore case and outsourcing, which are the two pillars in our study matrix.

• **MQ4**. Seventy percent of the selected papers were case studies, and only 9% were experiments. This low percentage can be explained by the extra effort required to evaluate goals in global settings. GSD research is hampered by distance and the difficulty involved in finding suitable industrial projects[120], which suggests that there may be a lack of collaboration between software companies and researchers. Moreover, only 4% of the selected articles reported the use of industrial experiments in their research. The authors of 15% of the selected papers employed surveys to collect quantitative information about SPM approaches for GSD .

• **MQ5**. The earliest evaluation research selected in this SMS was published in 2006, but real interest in evaluation research was not evident until 2010[20]. Evaluation research then became the predominant focus in the literature, due to the availability of previously reported SPM approaches for evaluation, validation, and comparison[10].

• **MQ6**. To establish a finding, well-known models must be taken into account. The PMBOK and SWEBOK knowledge areas constitute classification models and analysis with which to best match knowledge areas in software engineering management[5, 20, 99]. Few researchers have based their studies on SPM BOKs and standards, yet these BOKs and standards represent a lucid, precise, and detailed structure for analyzing results and putting work in its appropriate context. The flow of information among groups of processes in BOKs and standards should be taken into account by researchers who wish to see SPM for GSD succeed[5].

• **MQ7**. GSD has become a dominant paradigm in the software industry[11]. Its requirements for communication, collaboration, and knowledge management among team members have led researchers to propose approaches for these purposes. The potential benefits are considered to outweigh the challenges, due to the impact of one particular benefit[103], "diverse knowledge and market proximity". Other benefits include an improved understanding of agile practices and working styles, better teamwork, higher product quality, and lower overall project cost[63]. This benefit has also been determined to be critical to the successful performance of a GSD project.

In an outsourced project, the outsourcer assigns the responsibility of project management to the project manager in the outsourcing country[98]. That project manager is then responsible for project planning, risk management, time management, team management, and other project-related issues. The use of CMMI models has been proven to minimize and prevent risks, especially in processes that involve outsourcing vendors[5]. Various approaches for facilitating offshore work and effectively managing GSD are presented: XP, RBV, and its extension "Dynamic Capabilities". XP methodologies[88] reduce the number of communication delays and improve communication quality. RBV[64] helps identify the key project management capabilities associated with offshore application development. The Dynamic Capabilities framework extends RBV by adding a time-based capacity for either renewing or improving the resources to better meet the needs of a changing competitive environment[121]. Our results indicate that to fully realize the benefits of offshore outsourcing, it is critical to define the nature of the project, identify the major inter-organizational challenges associated with distributed projects during the software development life cycle, and identify the most effective approaches that will likely be required. The limited opportunity for direct communication in GSD makes necessary the effective use of indirect communication. Although indirect communication can vary depending on the approach used, the COCOMO, flow mapping, and Quadratic Assignment Procedure (QAP) techniques are reported to minimize and facilitate communication planning and management. Procura and GA are two approaches that help project managers to optimize planning and scheduling using a hierarchical top-down approach. Two aspects must be covered: the establishment of effective guidelines and an iterative modeling process. Both can be realized using a multi-criteria decision model and the VTManager method, but the question remains of how to ensure that they become living documents. For this purpose, a template document can be adapted to different circumstances as an artifact for use in global software projects. The document layout includes a changing control and revision section, a document introduction, a planning release section, a complexity estimation section, an iteration planning section, and a summary section. The template is developed using a casual workflow much like software is constructed using agile methods[122]. Estimation models provide information about estimating each feature to be developed, using line of codes estimation, user stories estimation, or simply development hours estimation.

6.2 Implications for researchers and practitioners

Our SMS results have implications for researchers in the SPM-for-GSD domain, since they will enable the identification of approaches reported in the literature. With regard to implications for practitioners, in this review, we determined that few experimental studies have been conducted in industrial environments, which may imply that the industrial application of SPM for GSD is quite limited. Accordingly, we suggest that practitioners cooperate with researchers to investigate the potential for applying new approaches in their practices. These findings indicate that the field is as yet immature in terms of its problem orientation rather than solution-orientation, particularly with respect to empirically evaluated solutions. Furthermore, we offer the following recommendations.

Practitioners such as software developers, project managers, and researchers involved in GSD project management should read articles published in the proceedings of the ICGSE conference and its affiliated workshops, in addition to papers in journals that specialize in research and practical experience, and thus contribute to the overall general improvement of software development practices. The Journal *IEEE Software* addresses issues and practices, and includes methods and techniques with which to better engineer software and manage its development. The Journal *Empirical Software Engineering* is a useful resource for finding empirical research published in scientific journals that specialize in the software project domain. The above list represents the main publication sources for studies related to SPM for GSD, while also serving as resources to which researchers are encouraged to send their articles.

A much smaller group of papers discusses successful practices and shares the lessons learned from them[45, 72, 90]. Practitioners could therefore benefit by considering these practices with respect to the adoption, construction, and development of SPM approaches for the GSD context[123]. Researchers may benefit from this SMS review by choosing among the SPM-for-GSD approaches to find that which best fits their needs. More studies involving recent SPM-for-GSD approaches are needed to promote the development of skills that will solve the challenges associated with distributed software, particularly the need to focus on this development as critical to the future of the software development business.

The result of this SMS shows that SPM-for-GSD related subjects appear to require further investigation by researchers, particularly approaches for addressing challenges related to contextual information management, knowledge management, and performance management in GSD[11]. Further research is needed regarding distributed software project activities, since communication, coordination, and software application costs become increasingly more difficult with increases in project size[7]. The best example of the potential utility of an approach and its classification is the benefits researchers may obtain by mapping the benefits and limitations of SPM approaches for GSD.

7 Threats to Validity

Below, we discuss the potential threats to validity and the steps that have been taken to mitigate or minimize these threats[124].

• **Construct validity:** The threats to construct validity in an SMS are related to the identification of primary studies[125, 126]. High-quality SMSes are based on a stringent search process. To obtain an exhaustive list of relevant primary studies, we advise the use of a carefully designed search string comprising an extensive range of terms. Since there are different terms available for introducing key words, the obtained results might not be comprehensive. This can be attributed either to an inadequate search process or the fact that terms were missing from the search string, which may have affected the final list of papers selected. In our study, we built the search string iteratively and performed a systematic search using an extensive range of terms to widen our research scope. The inadequate identification of these search keywords can be identified as a threat to construct validity.

The search in this study was performed using the IEEE Digital Library, ACM Digital Library, ScienceDirect, SpringerLink, and Google Scholar. Although this limited number of sources may represent a threat to validity, we considered the primary studies identified (84 papers), the information retrieved and the papers published in the main conference on GSE (ICGSE) to be sufficient to gain an in-depth understanding of the topic.

The references in the selected studies were not scanned to identify further studies. Nonetheless, an important number of articles (37 968) were identified through databases, and all of these papers were checked by their title, at the very least, to determine their relevance to this study.

• **Internal validity:** Internal validity deals with data extraction and analysis[125, 126]. Two authors performed the data extraction and classification of the primary studies, and the others reviewed the final results. The decision as to which data to collect and how to classify the papers was based on the judgment of the authors conducting the SMS. These authors, who are from different cultures and research groups, performed two different classifications to ensure reliability[35]. We mitigated the reliability threat using the Kappa coefficient, and achieved a score of 0.9, which indicates a high conformity level. As such, the internal validity threat in this study is minimal and had only a minor influence on the general classification derived.

When conducting the SMS, we excluded no articles on the basis of their quality. Although some researchers might prefer to exclude articles of poor quality, including them served to clarify and develop the results of our SMS and allowed us to enrich our discussion.

• **Conclusion validity:** In the case of an SMS, this threat refers to factors such as missing studies and incorrect data extraction[125, 126]. The aim is to control these factors so that an SMS performed by different researchers will yield the same conclusions. Bias in the selection and classification of primary studies and data analysis may therefore affect the interpretation of the results. To mitigate this threat, every step in the selection and data extraction process was clearly described. The traceability between the data extracted and the conclusions drawn was strengthened via the use of a statistical package to directly generate charts and tables from the data. In our opinion, slight differences due to publication selection bias and misclassification would not alter our main conclusions drawn from the articles included in our SMS. The threat to conclusion validity is thus adequately covered.

• **External validity:** External validity is related to the ability to generalize the findings of this study[127, 128]. This SMS considers the GSD domain and the validity of its conclusions concerns the GSD context. As such, this threat is not relevant in this context. The results of this study may serve as a starting point for researchers in SPM for GSD, and practitioners can search for and categorize additional papers.

8 Conclusion and Future Work

This work is an SMS in which papers relevant to SPM for GSD were analyzed along with factors contributing to the success of GSD projects. We can briefly describe the status of SPM approaches applied in the GSD arena via a SWOT analysis[19], wherein we address the strengths, weaknesses, opportunities, and threats of the SPM approaches for the GSD arena. These four factors confirm the use of SPM approaches within the scope of GSD, as well as the issues to be resolved, profitable areas for development, and measures to be addressed by the SPM-for-GSD community.

The SPM baseline is one of its most relevant strengths. It is a robust and mature field with a wide range of empirical evaluations of its methods, techniques, and tools in the industrial context. This baseline provides and combines multiple data sources for cross-validation. Furthermore, it explores issues raised by earlier studies. In addition, SPM for GSD is a productive field in which achievements are disseminated and new research projects are encouraged.

With regard to weaknesses, SPM for GSD is an emerging research field whose problems are being addressed by just a few researchers. Most studies have been published since 2006, following the establishment of the ICGSE conference that specializes in distributed projects. Most of the SPM-for-GSD approaches represent the implementation of processes to explore theoretical issues rather than make contributions to extending the field.

The range of opportunities in SPM for GSD is huge. Software developers are using software engineering management approaches to deal with proximity issues and inadequate processes. Developers have proposed approach usage patterns that are not enforced by processes. They are adapting approaches and applying social interaction and emergent processes, to make available approaches that will meet their coordination needs.

The threats to SPM for GSD are the constraints that prevent, delay, and obstruct its rational and formal development. These obstacles are mainly represented by the natural limitations that an incipient discipline has to confront. SPM for GSD must therefore address its lack of any effective relationship between academia and industry. Extra effort should be made to effectively transfer technology from academic to industrial settings. An additional threat to this field is the lack of visualization and dissemination of contextual information based on the objectives, profile, context, and format of software projects.

The results obtained from this SMS provide a global overview of a relatively new topic that merits detailed investigation. However, each distributed project has its own needs which basically depend on its distribution characteristics, its activity, and the approaches it employs. These factors make this subject extremely broad and complex, which highlights the need to adapt both technical and organizational procedures for each of the specific needs of GSD.

In future work, criteria must be established for systematically studying SPM to reduce the risks associated with GSD projects that arise from temporal, geographical, and socio-cultural distances. Strategies, measures, and controls have yet to be fully explored in the literature[129]. The lack of comprehensive communication plans and models that could support project manager decision-making in GSD contexts has been identified[115]. The use of search methods and surveys with industrial collaborators would be a good option for identifying approaches that can address these challenges.

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